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Atmospheric Water Vapor Measurements During the SPECTRE Campaign using an Advanced Raman Lidar

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Abstract

An advanced Raman lidar has been designed to operate in both daylight and darkness. Details of the instrument will be presented. Results from operating during the SPECTRE Field Campaign will be discussed.

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Summary

Water vapor is an important atmospheric state variable. From a dynamics stand point its distribution with height determines convective stability, which in turn controls storm development. From a radiative perspective, current global warming scenarios suggest that water vapor may contribute as much as twice the anticipated atmospheric temperature increase that would be caused by anthropogenic carbon dioxide alone via a thermally induced feedback mechanism. Because atmospheric water vapor is radiatively active, accurate measurements with high spatial and temporal resolution are required to fully understand it's impact on future global surface temperature.

The SPECTral Radiation Experiment (SPECTRE) campaign conducted in Coffeyville, KS during the period Nov. 13 - Dec. 7 , 1991 was designed to acquire the important atmospheric measurements needed to test for the first time, in an unambiguous manner, radiative transfer models of the atmosphere. In addition to high resolution measurements of the atmospheric downwelling infrared radiation, accurate observations of temperature, water vapor and clouds versus altitude were needed to meet the objectives of the campaign. The instrument used to acquire high vertical resolution profiles of atmospheric water vapor during the experiment was an advanced Raman lidar.

The lidar is designed to operate during both daylight and darkness. The system consists of a high power excimer laser aligned with the optical axis of a 0.75-m diameter Dall-Kirkham telescope pointing horizontally toward the rear of an environmentally controlled van. During operations, a 0.8 x 1.1-m optical flat is positioned at a 45° angle on a rotatable shaft external and to the rear of the van. Rotation of the shaft allows for lidar observations at any elevation angle from one horizon through vertical to the other horizon in a plane perpendicular to the long axis of the van. During darkness the excimer laser produces radiation at 351 nm (XeF, 50 mJ per pulse at 400Hz); during daylight the laser operates in the solar blind region of the spectrum at a wavelength of 248 nm (KrF, 120mJ at 400Hz). The output of the telescope can be directed, by the use of a two-position mirror, into either a daytime or a nighttime detector package. Each detector package has four optical channels—one to observe backscatter at the laser wavelength, and the others to observe Raman backscatter from oxygen, nitrogen, and water vapor, using specially manufactured interference filters centered at the appropriate wavelengths. Because of the low intensities of the Raman signals, the filters for these channels have very high blocking at the laser wavelength. Each channel has a low sensitivity (sensing approximatly

2% of the signal) and a high sensitivity (98%) photomultiplier. The output of each of the eight photomultipliers (from either the daytime or nighttime detector package) is amplified and the photons are counted by an accumulating multi-channel (0.5μs binwidth) scalar. Signals from a large number of laser shots are accumulated before reading out the scalars (typically 23,200 during nighttime operation and 50,000 during daytime).

After correction for differential attenuation, the ratio of the Raman scattering from water vapor to that from nitrogen is proportional to the water-vapor-mixing-ratio, an important measure of atmospheric moisture. Figure 1 shows a time-height measure of water-vapor mixing ratio over a 10.5 hr period on Nov. 18, 1991. Data of this type will be discussed in more detail during the presentation.

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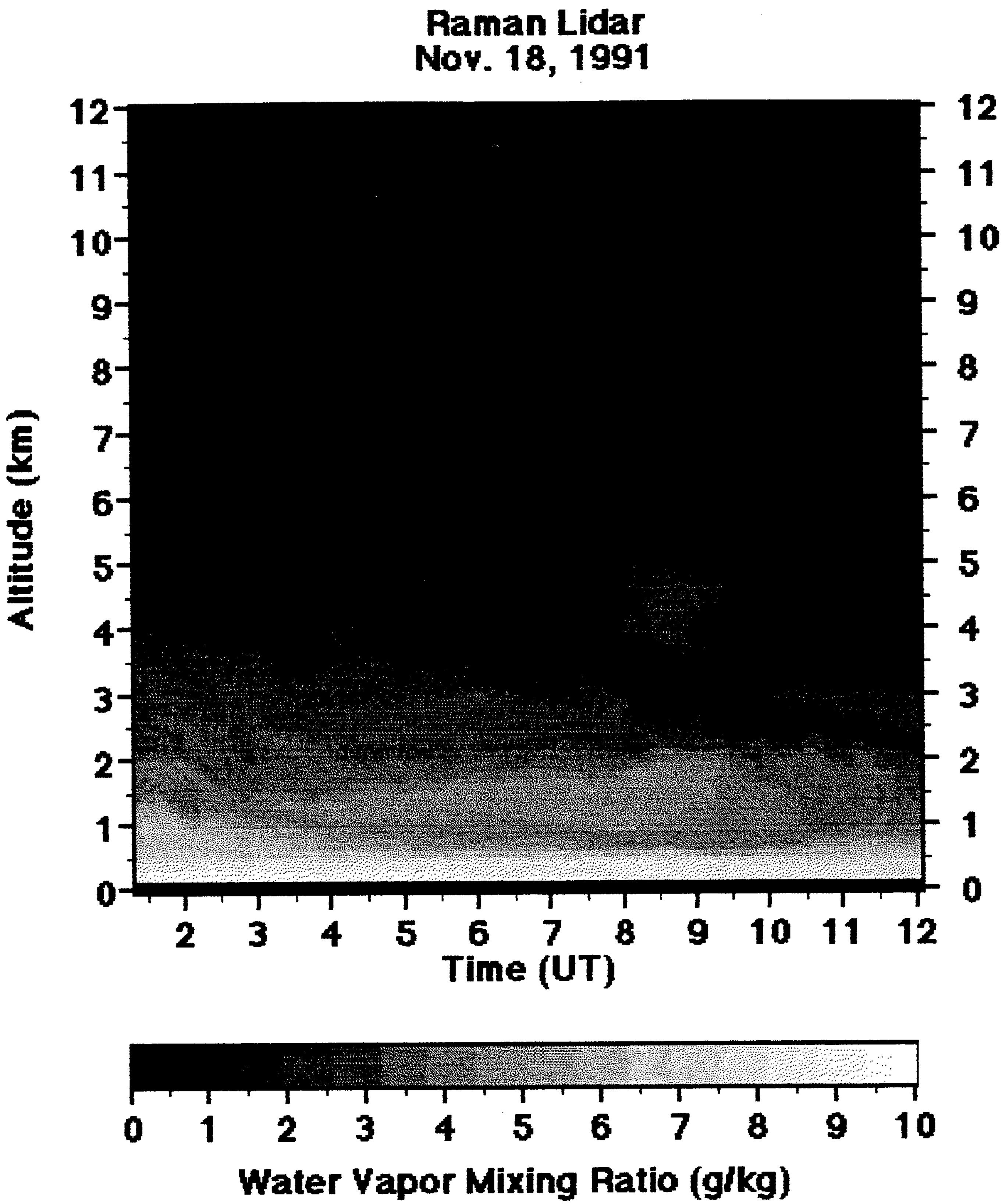
Figure Captions

1. A time-height display of water-vapor mixing ratio acquired during the SPECTRE field campaign on Nov. 18, 1991. The bar shows the relationship between the various shades of gray and the value of water-vapor mixing ratio.


Raman Lidar
Nov. 18, 1991
Altitude (km)
Time (UT)
Water Vapor Mixing Ratio (g/kg)
0
1
2
3
4
5
6
7
8
9
10
11
12